

Electroweak Physics and Top Quarks at DØ



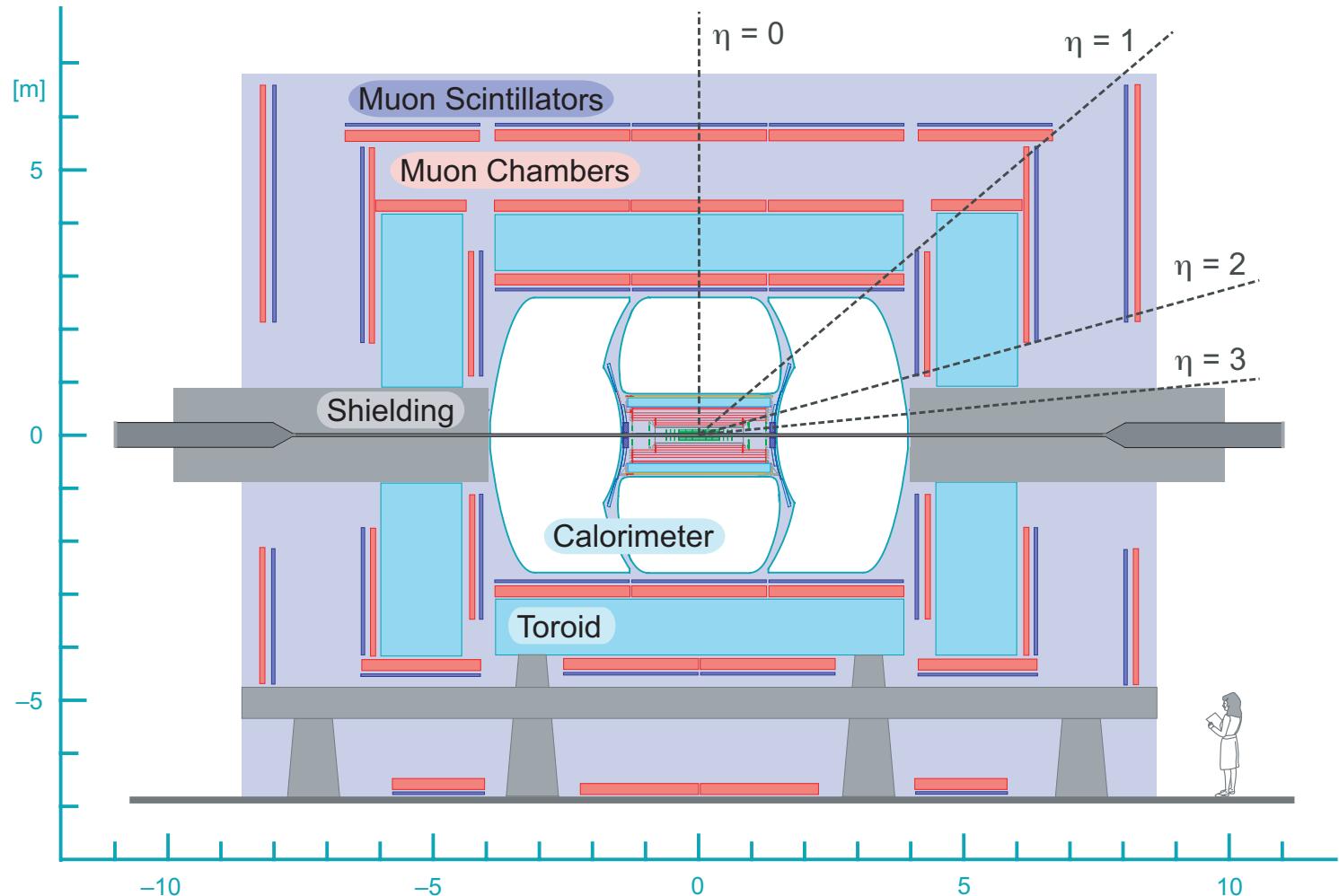
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University of California, Riverside

For the DØ Collaboration
Fermilab Annual Users' Meeting
Monday 2nd June, 2003

- W 's and Z 's
- Top quarks
- The Higgs hunt



The DØ Detector





DØ's Performance

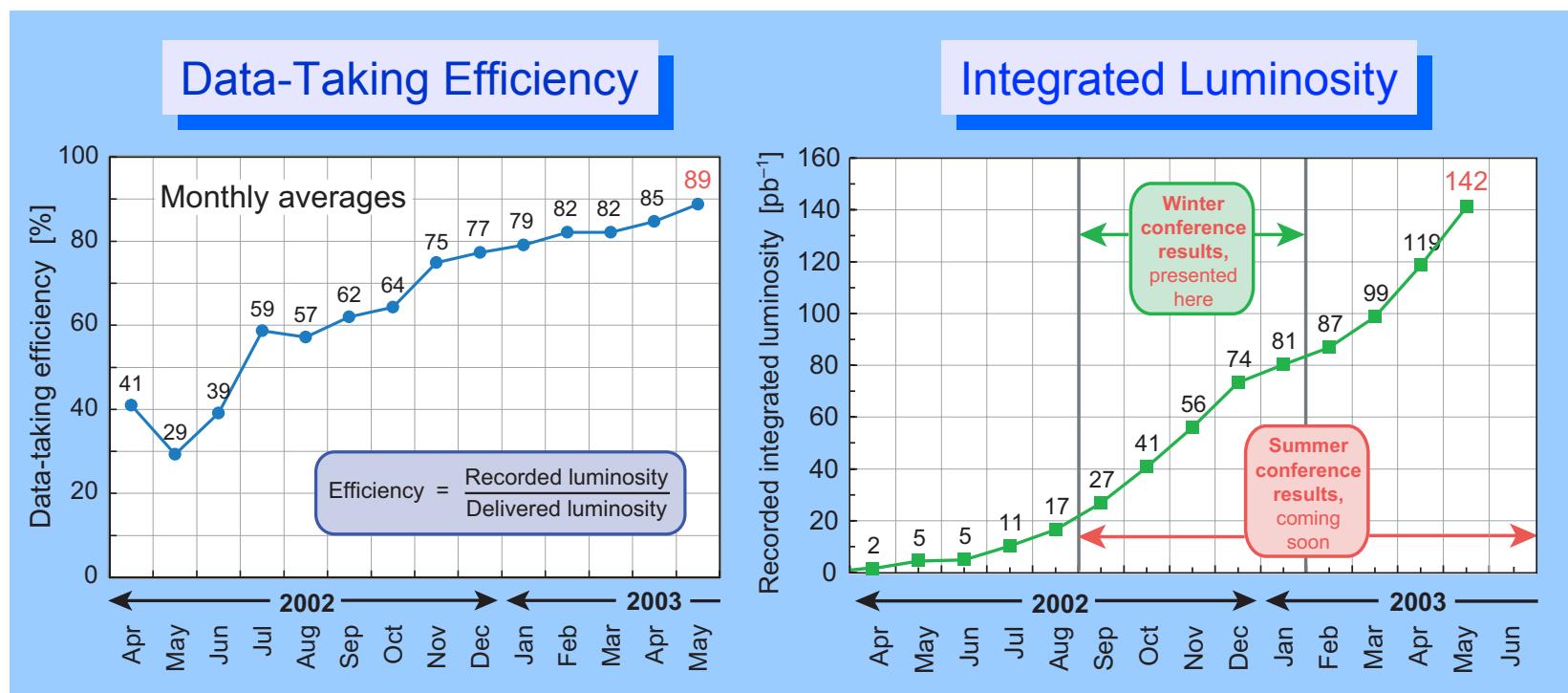
Detector completed: April 2002

Data (full detector): 134 pb^{-1}

Data-taking efficiency: $\leq 96\%$

Operating channels:

Silicon tracker	$\sim 91\%$
Fiber tracker	$\sim 99\%$
Calorimeter	$> 99.9\%$
Muon tracker	$> 99.5\%$



W and *Z* Bosons



- Test Standard Model electroweak couplings
- Test higher-order QCD corrections
- Constrain parton distribution functions of proton
- Optimize triggers and particle ID algorithms
- Calibrate integrated luminosity measurement
- Calibrate jet and electromagnetic energy scales
- Constrain fit for Higgs boson mass
- Measure backgrounds to top and Higgs

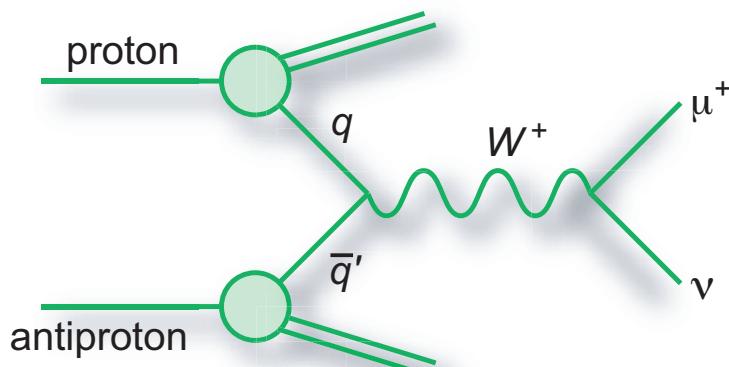


W and *Z* Bosons

Heavy particles

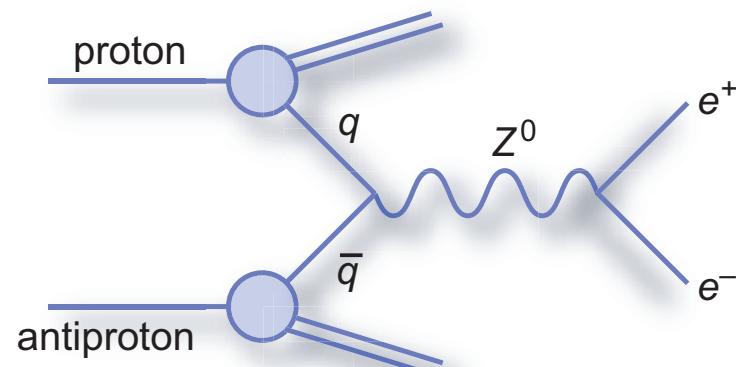
$$m_W = 80.423 \pm 0.039 \text{ GeV}$$

$$m_Z = 91.1876 \pm 0.0021 \text{ GeV}$$



$$\begin{aligned} \sigma(p\bar{p} \rightarrow W + X) \times B(W \rightarrow \mu\nu) \\ \approx 25 \text{ nb} \times 11\% \approx 2.8 \text{ nb} \end{aligned}$$

Large cross sections,
so very high statistics



$$\begin{aligned} \sigma(p\bar{p} \rightarrow Z + X) \times B(Z \rightarrow e^+e^-) \\ \approx 7.7 \text{ nb} \times 3.4\% \approx 0.26 \text{ nb} \end{aligned}$$



W Events

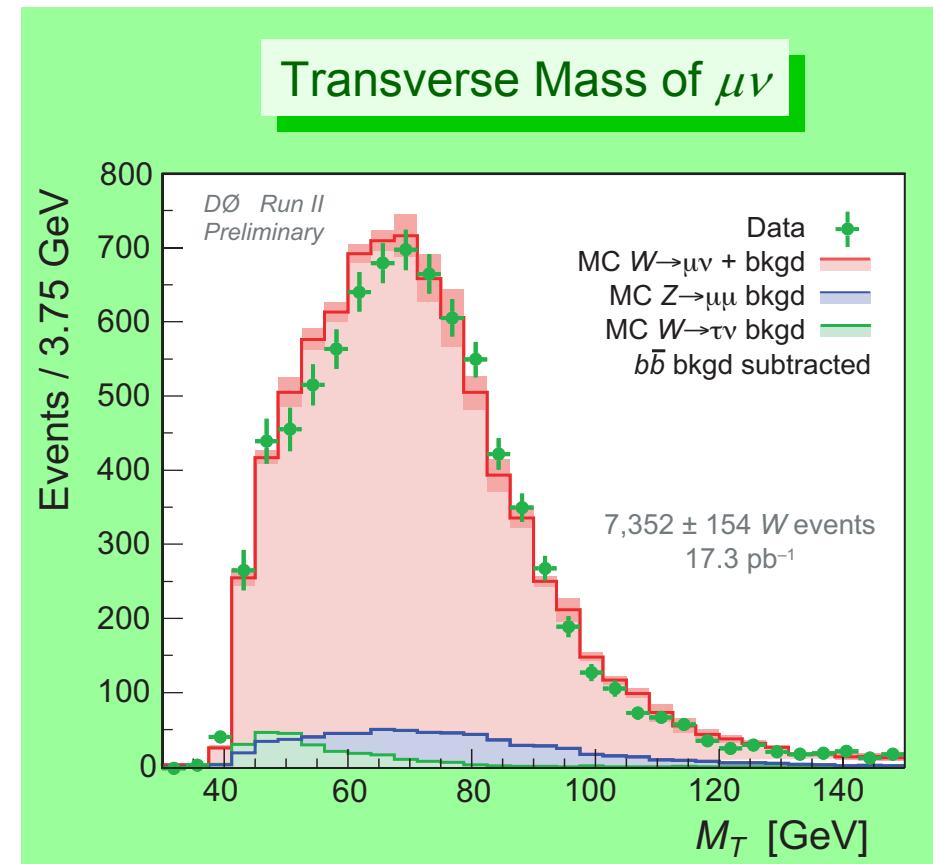
Muon channel

Data is 6% $b\bar{b}$
8% $Z \rightarrow \mu\mu$,
3% $W \rightarrow \tau\nu$
Signal:Background = 5:1

$$\sigma(p\bar{p} \rightarrow W+X) \times B(W \rightarrow \mu\nu) \\ = 3,226 \pm 128 (N_W) \\ \pm 100 (\text{syst}) \pm 323 (\text{lumi}) \text{ pb}$$

$$\sigma(p\bar{p} \rightarrow W+X) \times B(W \rightarrow e\nu) \\ = 3,054 \pm 100 (N_W) \\ \pm 86 (\text{syst}) \pm 305 (\text{lumi}) \text{ pb}$$

Cross section error dominated by error on integrated luminosity (10%)
This should go down to ~5% in the future





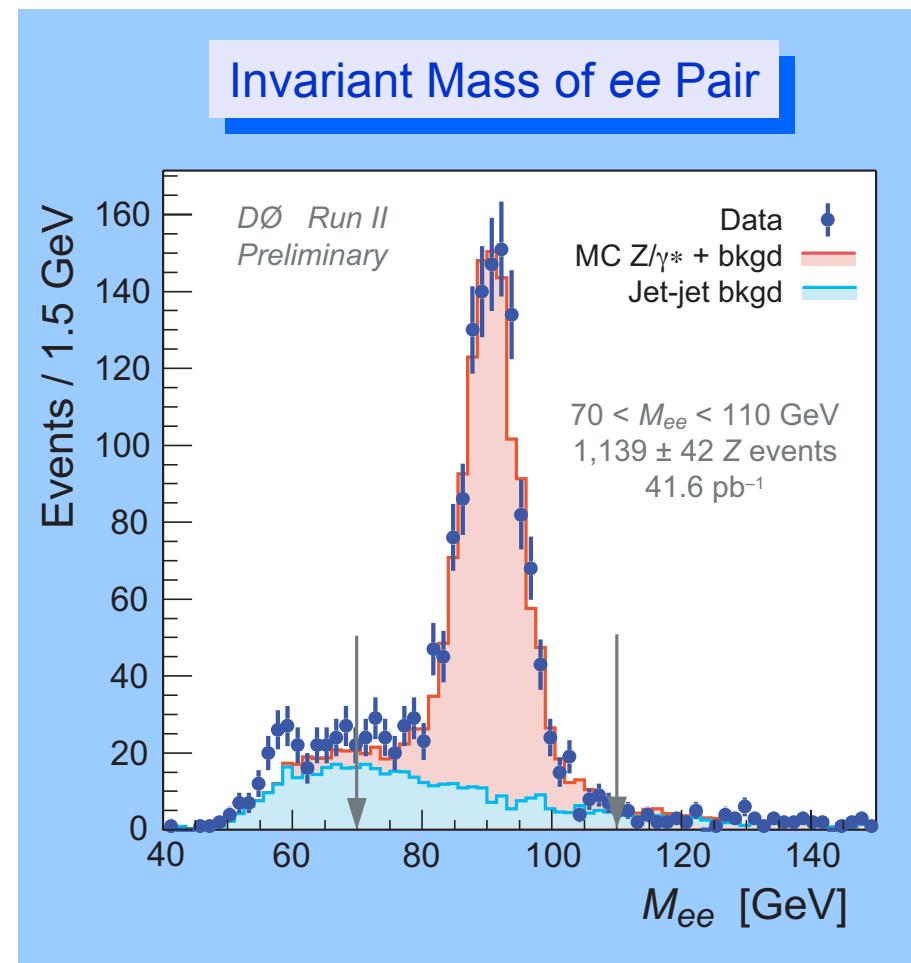
Z Bosons

Electron channel

Data is 18% multijets,
1.7% Drell-Yan
for $70 < m_Z < 110$ GeV
Signal:Background = 4:1

$$\begin{aligned}\sigma(p\bar{p} \rightarrow Z + X) \times B(Z \rightarrow ee) \\ = 294 \pm 11 (N_Z) \\ \pm 8 (\text{syst}) \pm 29 (\text{lumi}) \text{ pb}\end{aligned}$$

$$\begin{aligned}\sigma(p\bar{p} \rightarrow Z + X) \times B(Z \rightarrow \mu\mu) \\ = 264 \pm 7 (N_Z) \\ \pm 17 (\text{syst}) \pm 26 (\text{lumi}) \text{ pb}\end{aligned}$$





W & Z Prospects

Near term

Extend electron measurements
to forward region

Include calorimeter track in
muon identification

Improve MC models

Longer term

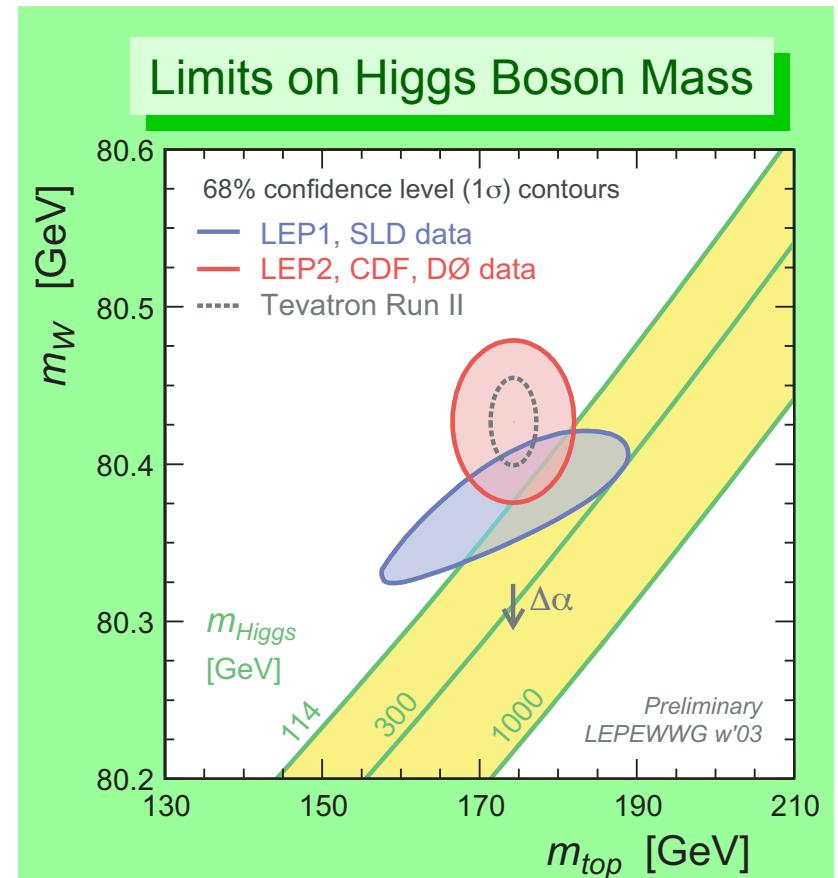
Dibosons, W and Z asymmetries
 W boson width and mass

DØ's Run I W mass error = 84 MeV

World average error = 34 MeV (0.04%)

Prediction for Run II (per expt., 2 fb^{-1}) = 30 MeV

⇒ Improve limit on Higgs boson mass



Top Quarks

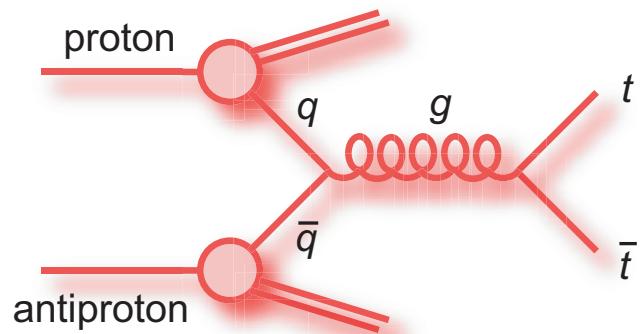


- Within the Standard Model:
 - Constrain Higgs boson mass with top quark mass measurement
 - Test higher order QCD calculations with $t\bar{t}$ cross section
 - Test Wtb coupling with single top cross section
 - Test model of top quark spin and decay particle helicity
 - Search for rare decays
- Beyond the Standard Model:
 - Search for high mass particles decaying to $t\bar{t}$ pairs
 - Search for exotic decays



$t\bar{t}$ Overview

Top quarks are very heavy, so only produced at the Tevatron



$t\bar{t}$ cross section is 30% higher in Run II than in Run I

$$\sigma(p\bar{p} \rightarrow t\bar{t} + X) \approx 7.5 \text{ pb}$$

(NNLO, $\sqrt{s} = 1.96 \text{ TeV}$, $m_{top} = 175 \text{ GeV}$, CTEQ5M, Kidonakis *et al.*)

⇒ This is still tiny, only 0.03% of the W boson cross section

DØ identified 41 $t\bar{t}$ events in Run I

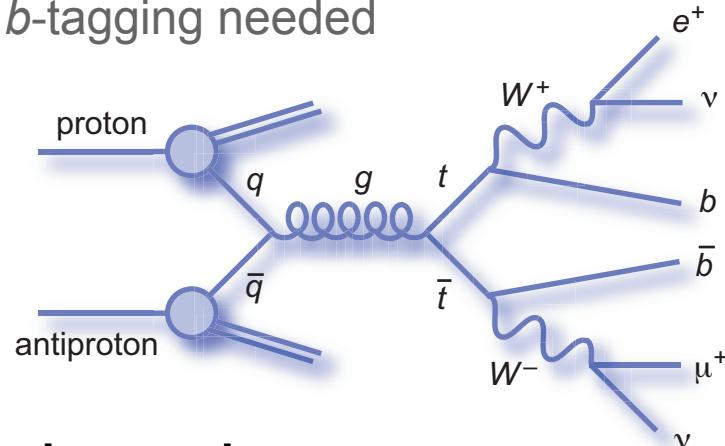
Expect several thousand events in Run II

Many exciting new measurements possible with more data



Dilepton Decays

Small branching fractions to ee, e μ , $\mu\mu$, but few sources of small backgrounds, so no b -tagging needed



Backgrounds:

$WW(\rightarrow ee, e\mu, \mu\mu) + \text{jets}$

$Z(\rightarrow ee, \mu\mu) + \text{jets}$

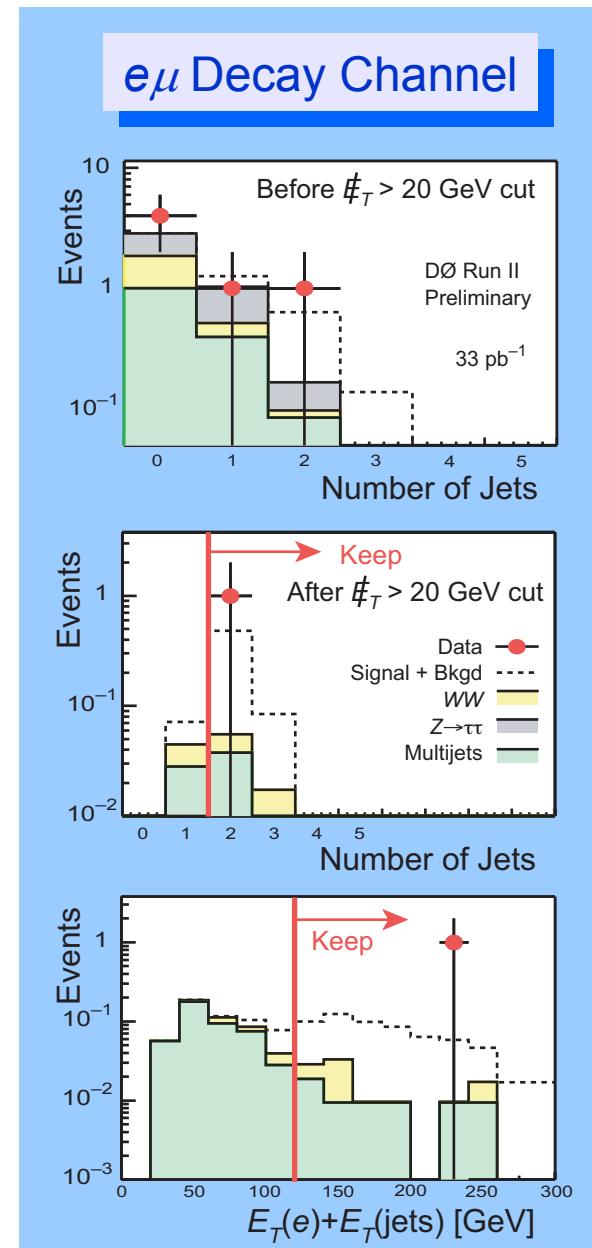
$b\bar{b} + \text{jets}$

$Z(\rightarrow \tau\tau \rightarrow e\mu) + \text{jets}$

multijets

	ee	e μ	$\mu\mu$
Background	1.00 ± 0.48	0.07 ± 0.01	0.59 ± 0.30
Expected signal	0.25 ± 0.02	0.50 ± 0.01	0.30 ± 0.02
Signal+Bkgd	1.25 ± 0.48	0.57 ± 0.48	0.89 ± 0.30
Data	4	1	2

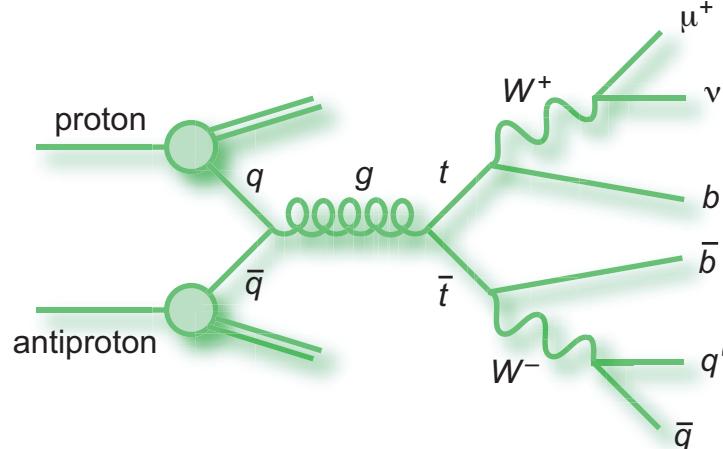
Ann Heinson





Lepton+Jets Decays

Larger branching fractions than to dileptons,
but backgrounds higher, so b -tagging useful



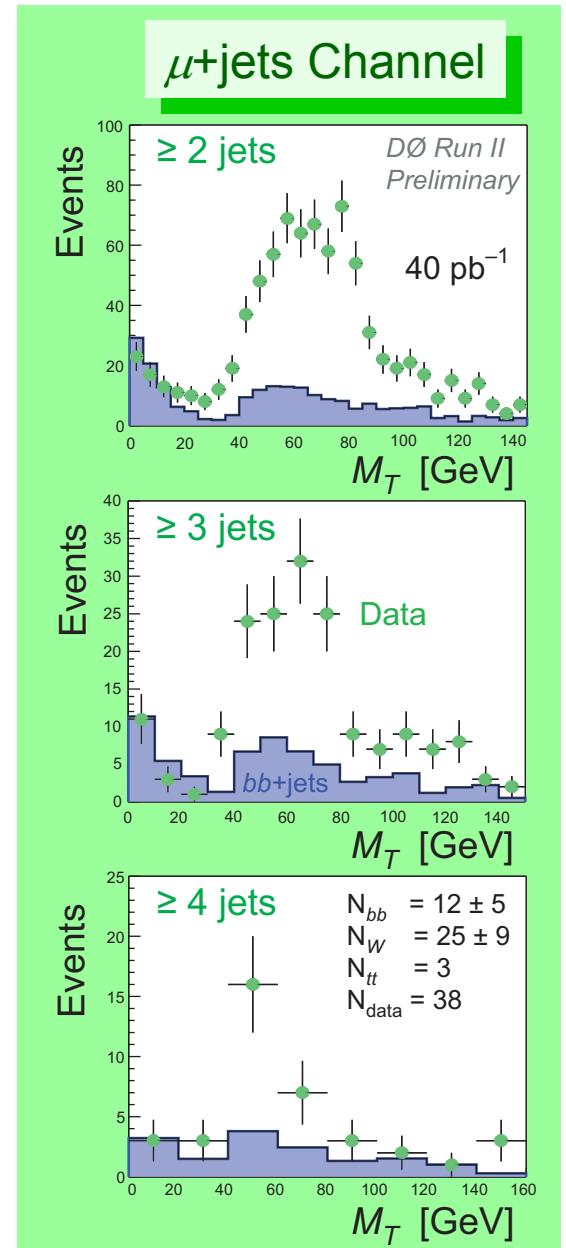
Backgrounds:

$W (\rightarrow e, \mu)$ +jets

$b\bar{b}$ +jets

multijets

	e+jets	$\mu +\text{jets}$	$e+\text{jets}/\mu$	$\mu+\text{jets}/\mu$
Background	2.7 ± 0.6	2.7 ± 1.1	0.16 ± 0.10	0.74 ± 0.38
Expected signal	1.8	2.4	0.54	0.82
Signal+Bkgd	4.5	5.1	0.70	1.56
Data	4	4	2	0





Top Physics Prospects

$$\sigma(p\bar{p} \rightarrow t\bar{t} + X)$$

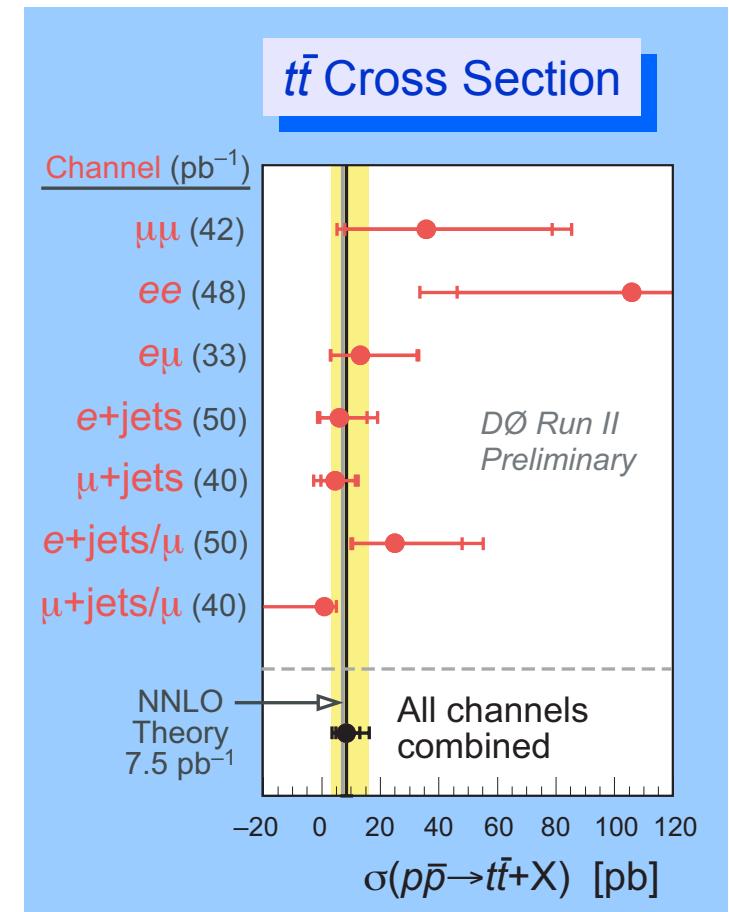
$$= 8.4^{+4.5}_{-3.7} \text{ (stat)}^{+5.3}_{-3.5} \text{ (syst)} \pm 0.8 \text{ (lumi) pb}$$

Near term

Cross section using vertex b -tagging
Top mass measurement

Longer Term

Observe single top quark production
Measure top quark mass with 2 GeV error





Top Quark Mass

DØ's Run I measurement using 77 lepton+jets events found:

$$m_{top} = 173.3 \pm 5.6 \text{ (stat)} \pm 5.5 \text{ (syst) GeV} \quad (3.2\% \text{ stat error})$$

A recent new analysis of 22 of these events finds:

$$m_{top} = 180.1 \pm 3.6 \text{ (stat)} \pm 4.0 \text{ (syst) GeV} \quad (2.0\% \text{ stat error})$$

⇒ Improved sensitivity equivalent to 2.4 times more data

New method:

All features of individual events are included, so well-measured events contribute more information than poorly-measured ones

Total error on top quark mass measurement from all decay channels from CDF and DØ combined is **2.9%**

Total error from this one new measurement with only a few events is **3.0%**

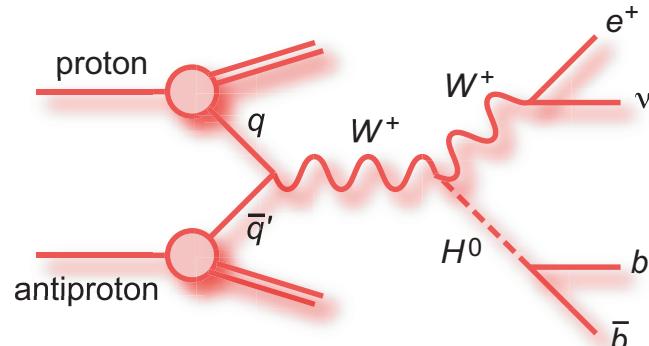
Higgs Expectations



- Standard model Higgs boson:
 - $m_H > 114.4 \text{ GeV}$ (95% CL) Direct searches by LEP expts
 - $m_H < 211 \text{ GeV}$ (95% CL) Indirect result from a fit to data
- Many additional Higgs bosons in other models
- Searches are underway at DØ
- Very demanding analyses, all tools must be optimized
- Many inverse femtobarns of data needed for observation



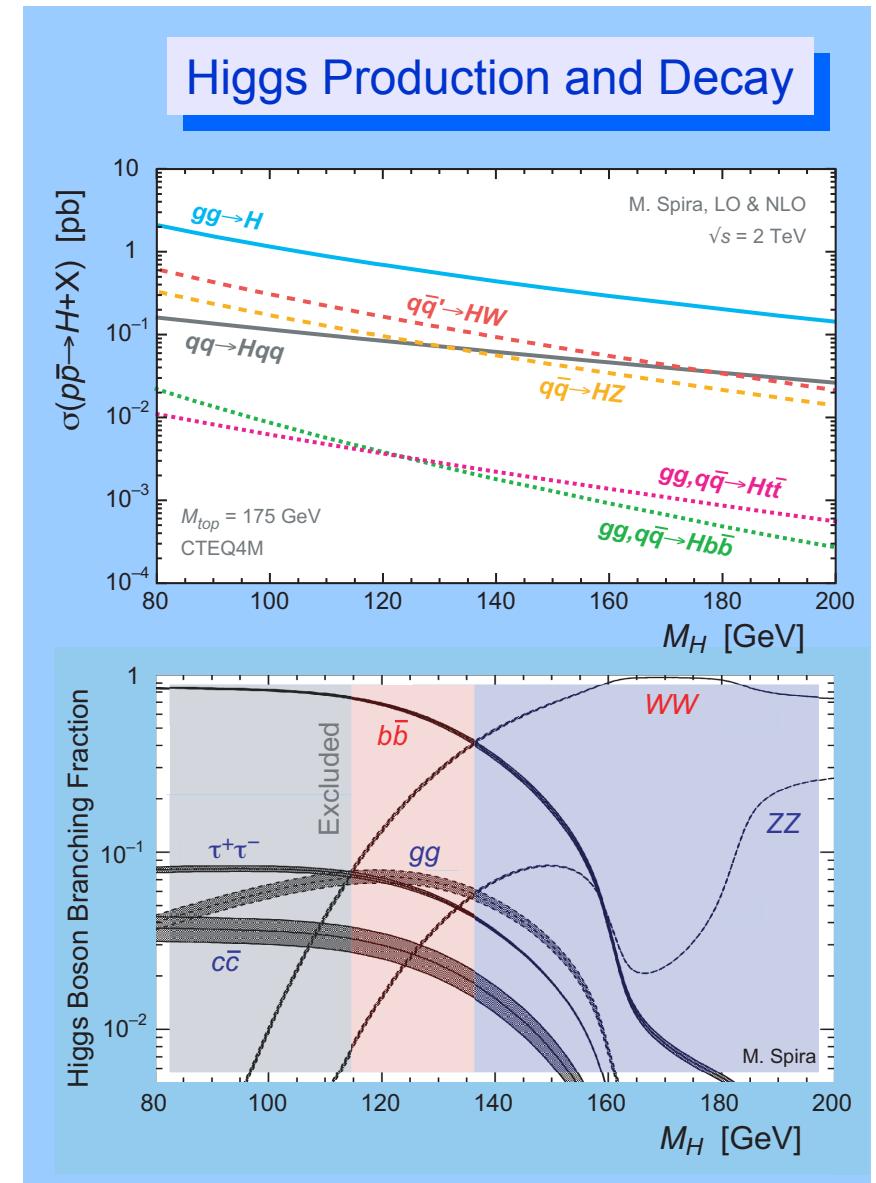
Higgs Overview



Low mass search mode

At $m_H = 115 \text{ GeV}$:

$$\begin{aligned} & \sigma(p\bar{p} \rightarrow HW + X) \\ & \times B(H \rightarrow b\bar{b}) \times B(W \rightarrow e\nu) \\ & \approx 0.13 \text{ pb} \times 70\% \times 11\% \\ & \approx 0.01 \text{ pb} \end{aligned}$$



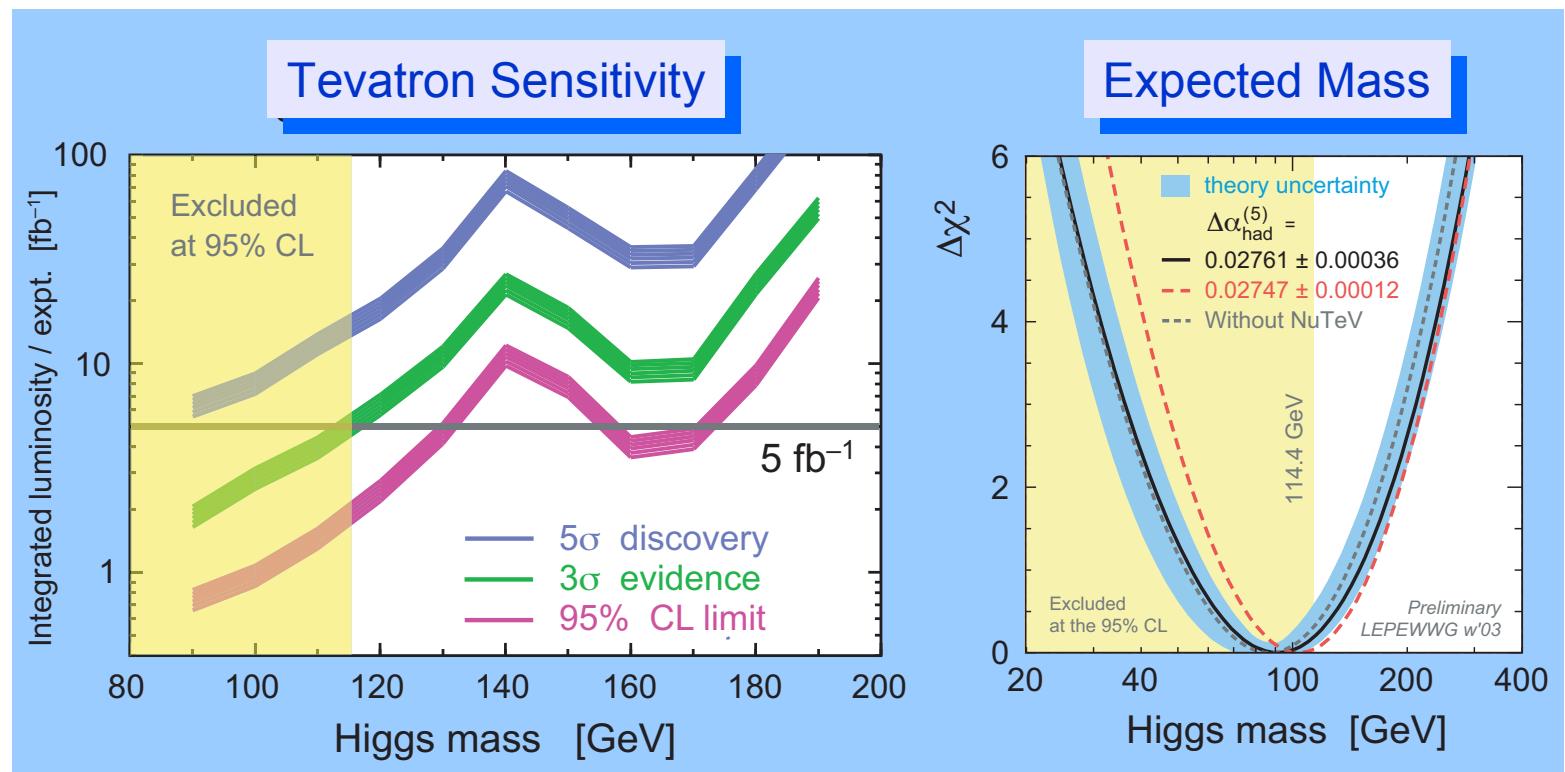


Higgs Search Method

Combine **six decay channels of HW and HZ**

from CDF and D \emptyset , with improved b -tagging, jet resolutions, neural networks, etc.

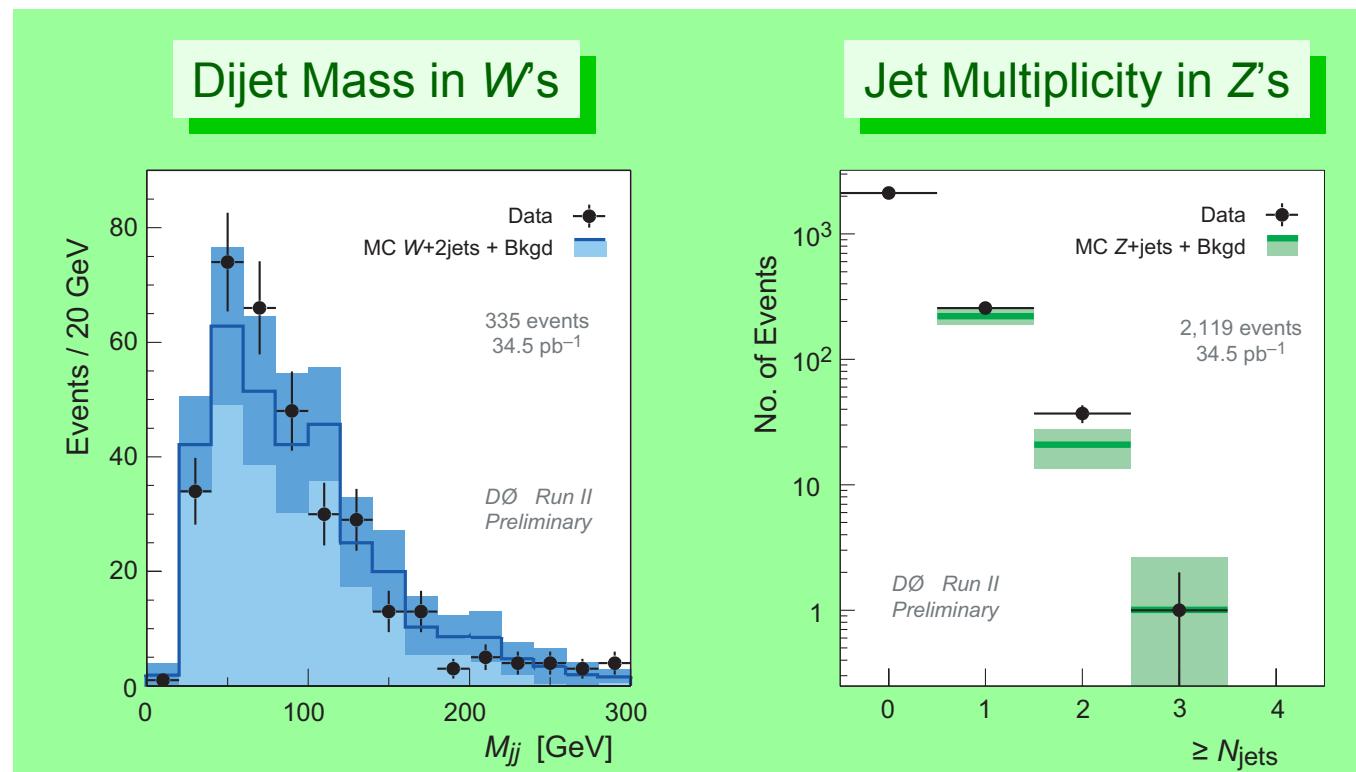
⇒ Rule out the SM Higgs boson up to \sim 120–130 GeV





Background Studies

Understanding backgrounds is critical for Higgs boson searches
Need high b -tag efficiency and low mistag probability
Excellent dijet mass resolution is essential for separating Higgs decays to $b\bar{b}$ from multijet backgrounds



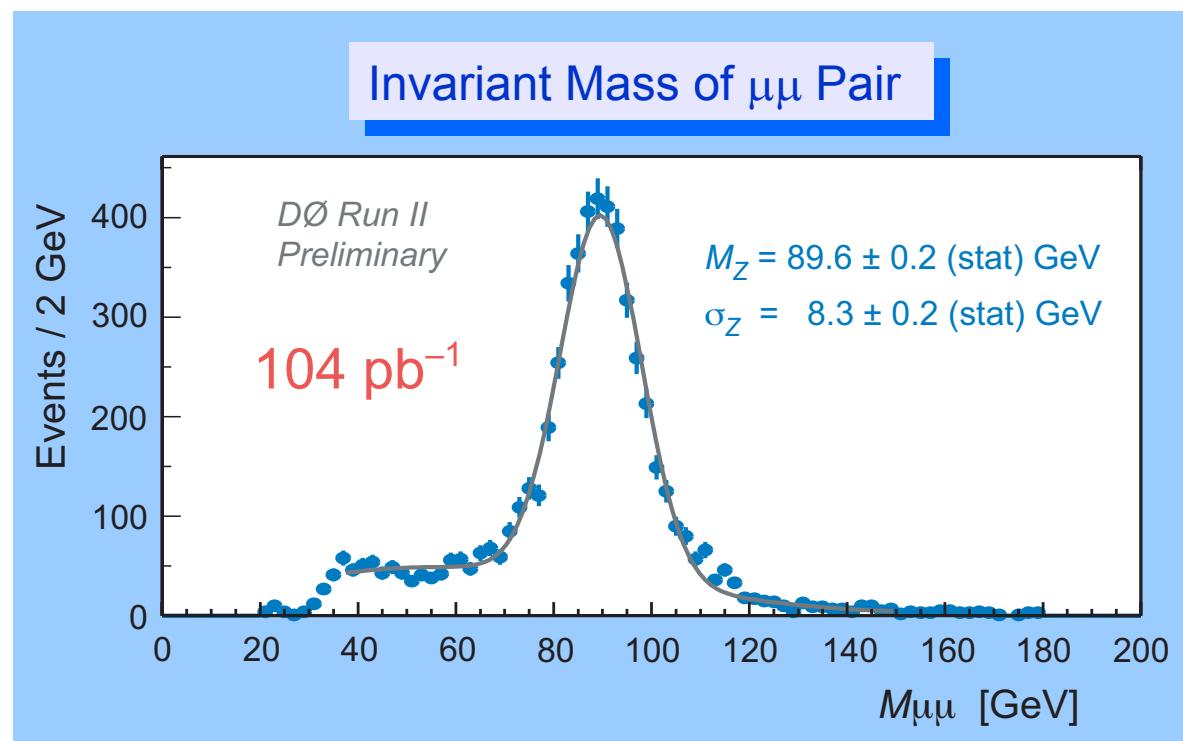


A Taste of the New Data

⇒ First public plot from DØ with $>100 \text{ pb}^{-1}$ of Run II data

Resolution is 8.3 GeV, approaching MC value of 6.6 GeV

Statistics will improve further when full dataset is re-reconstructed with the new tracking algorithms by the end of 2003





Summary

- ***W* and *Z* status**
 - First cross sections measured
 - Rich program of precision measurements ahead
- **Top quark physics**
 - Top quark re-observed at 3σ significance
 - Exciting work in progress, more results soon
- **Higgs search**
 - Background studies underway
 - Ready for more integrated luminosity
- **General outlook**
 - DØ is running efficiently
 - Full and varied program of electroweak and top quark physics underway